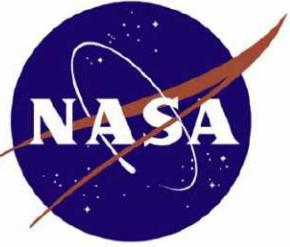


Effect of Crack Opening on Penetrant Crack Detectability

Space Grant Internship
June 8 – August 14

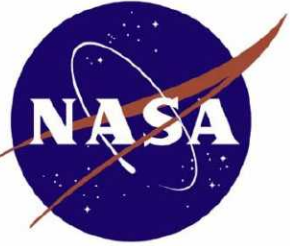
Devin Weaver



Agenda



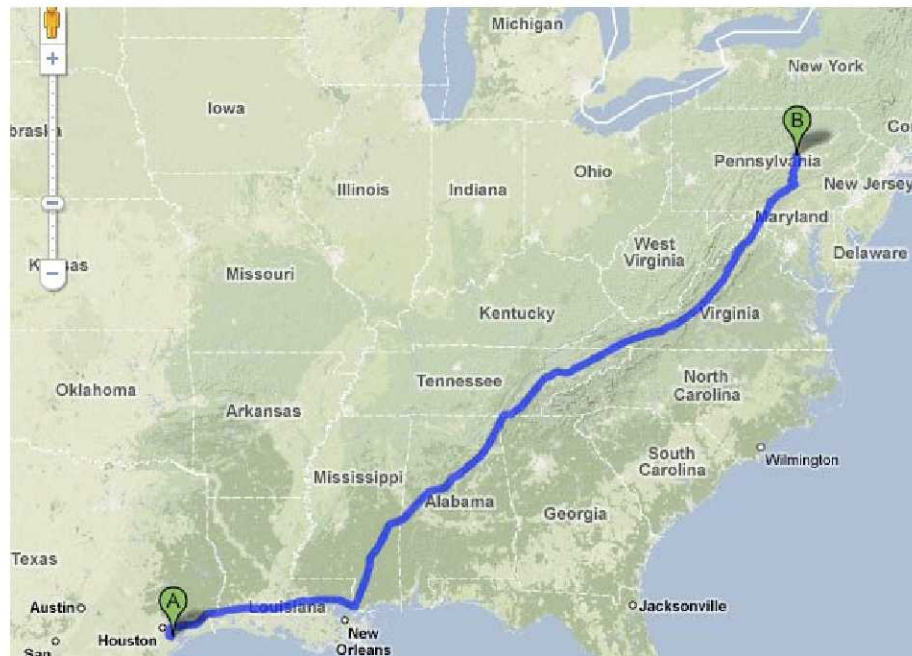
- Personal Background
- Background Information
- Project Outline
- Project Procedure
- Results
- Conclusion & Future Work
- What I Have Learned
- The Near Future
- Acknowledgements and References



Personal Background



Mechanical Engineering
Graduate in May 2010



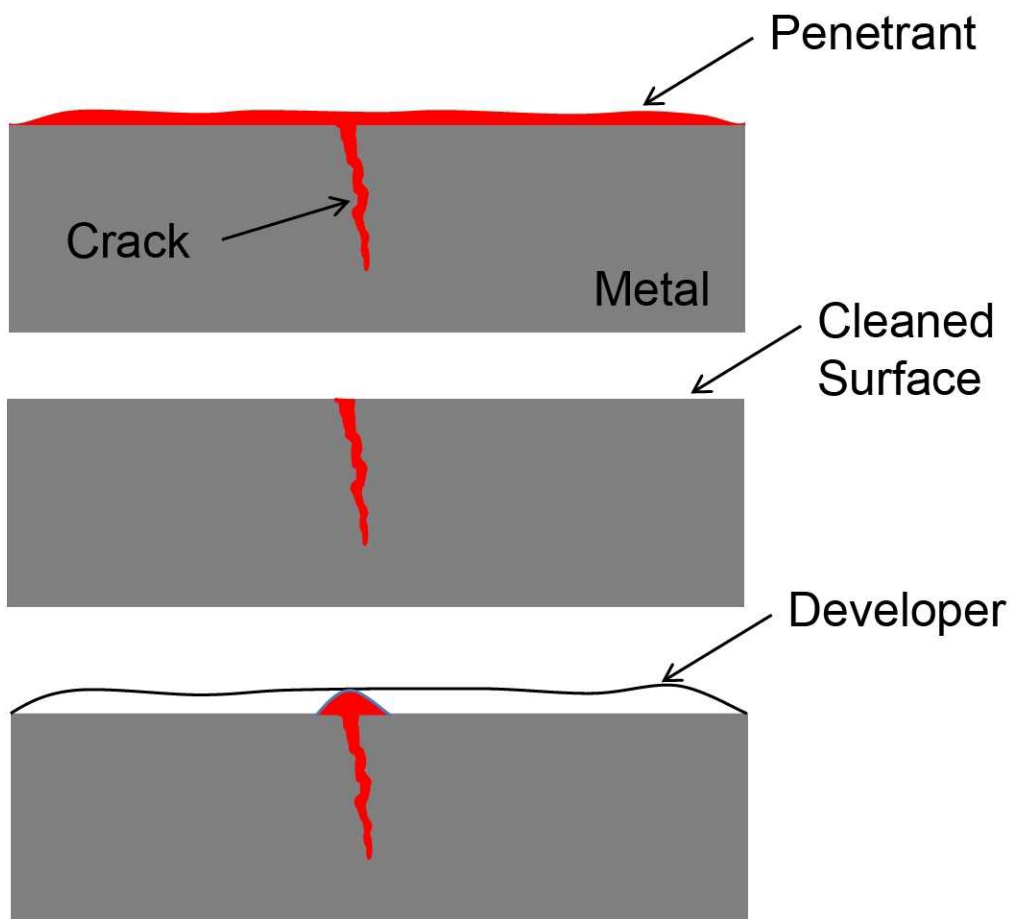


Background

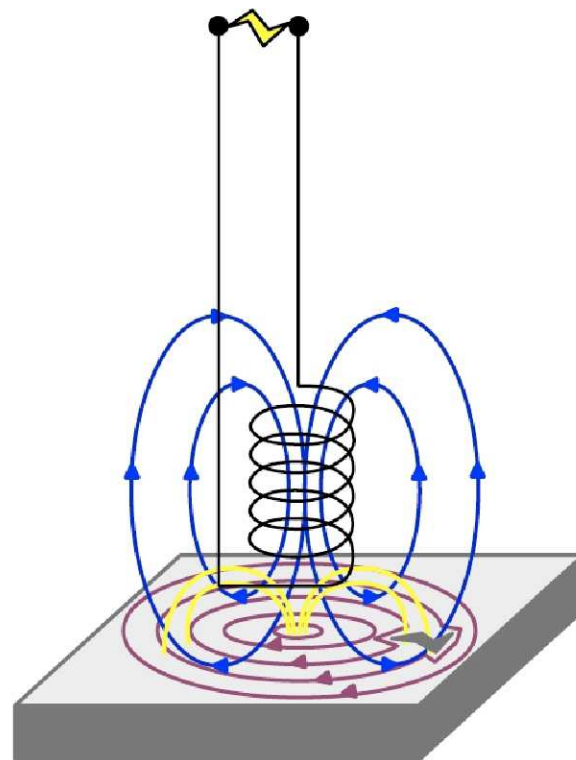
Non Destructive Evaluation (NDE)

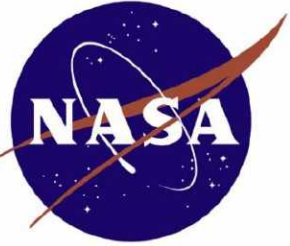


Fluorescent Penetrant Testing



Eddy Current Testing

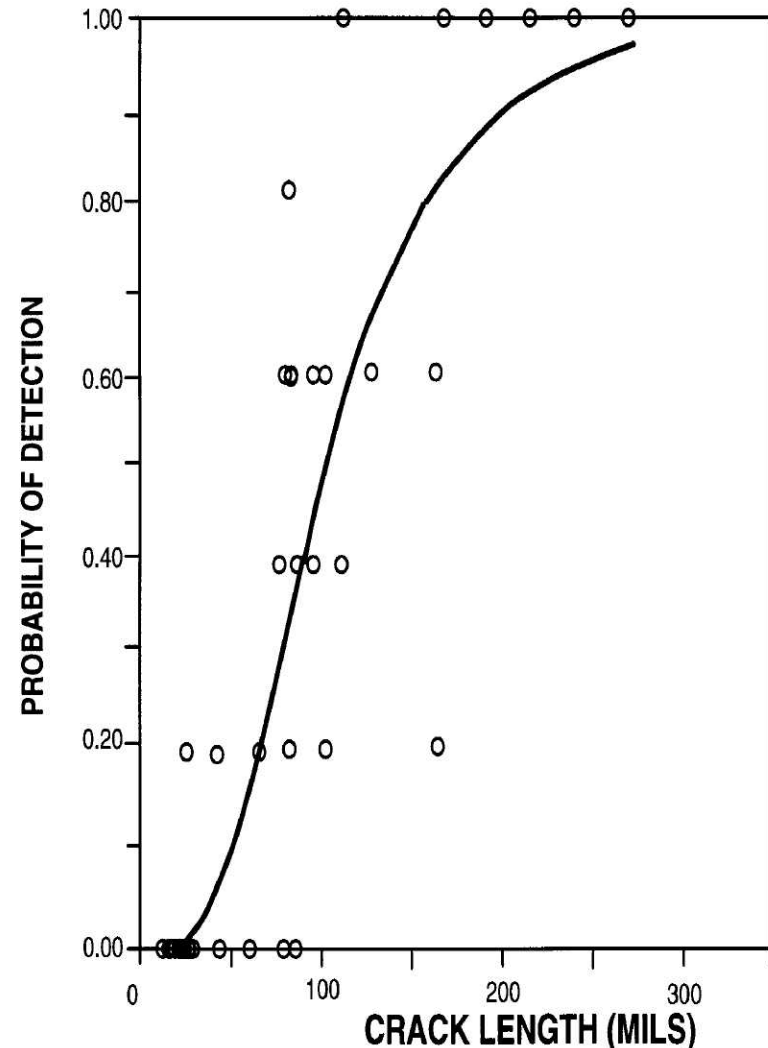


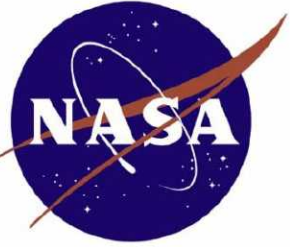


Background

Probability of Detection (POD)

- Quantitative measure of the efficiency of an NDE procedure in finding flaws of specific type and size
- The goal is to find a crack length for which there is 90% chance of detection with a 95% confidence
- NASA uses a 29/29 criteria while the Air Force uses regression analyses
- The JSC NDE lab has several sets of POD specimens



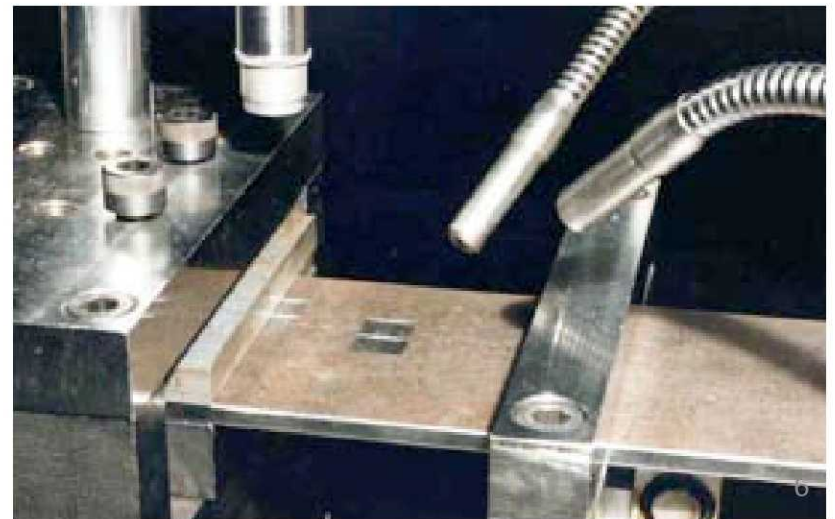


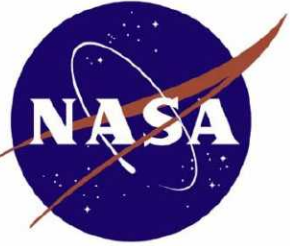
Background

JSC Titanium POD Specimens



- Semi-circular grooves cut into 4"x18" Ti Bar
- EDM slots placed in rib between grooves
- Fatigue cracks created by bending
- The grooves were machined off after cracking
- Surfaced etched to remove smeared metal that was covering the cracks





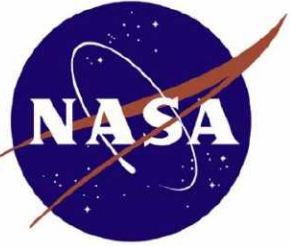
Background

Why?



- A NASA contractor required to pass POD test to build pressure vessels for Mars Science Laboratory
- Another NASA contractor could not find ultra-tight cracks in shuttle FCV poppets using fluorescent penetrant
 - Rely on eddy current testing to approve poppets for flight
 - Researching root cause of cracks at WSTF



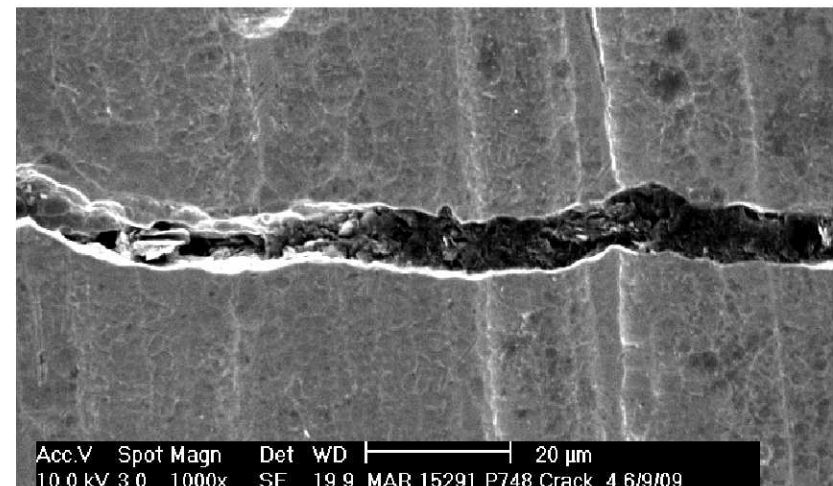
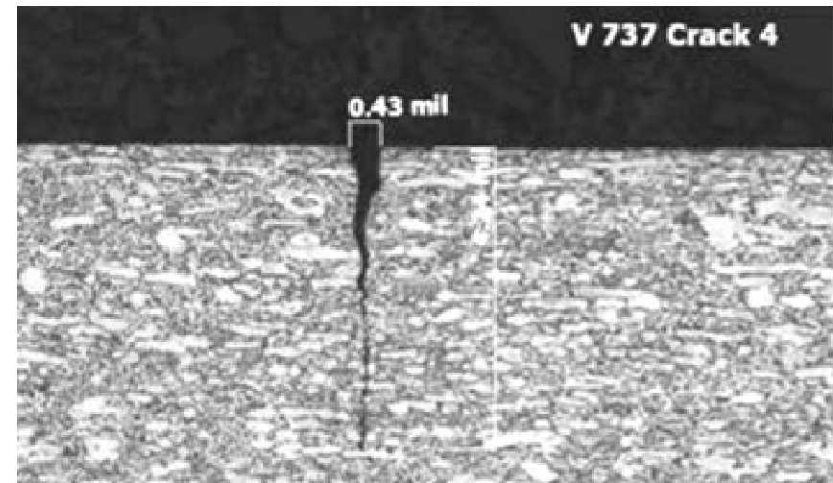


Background



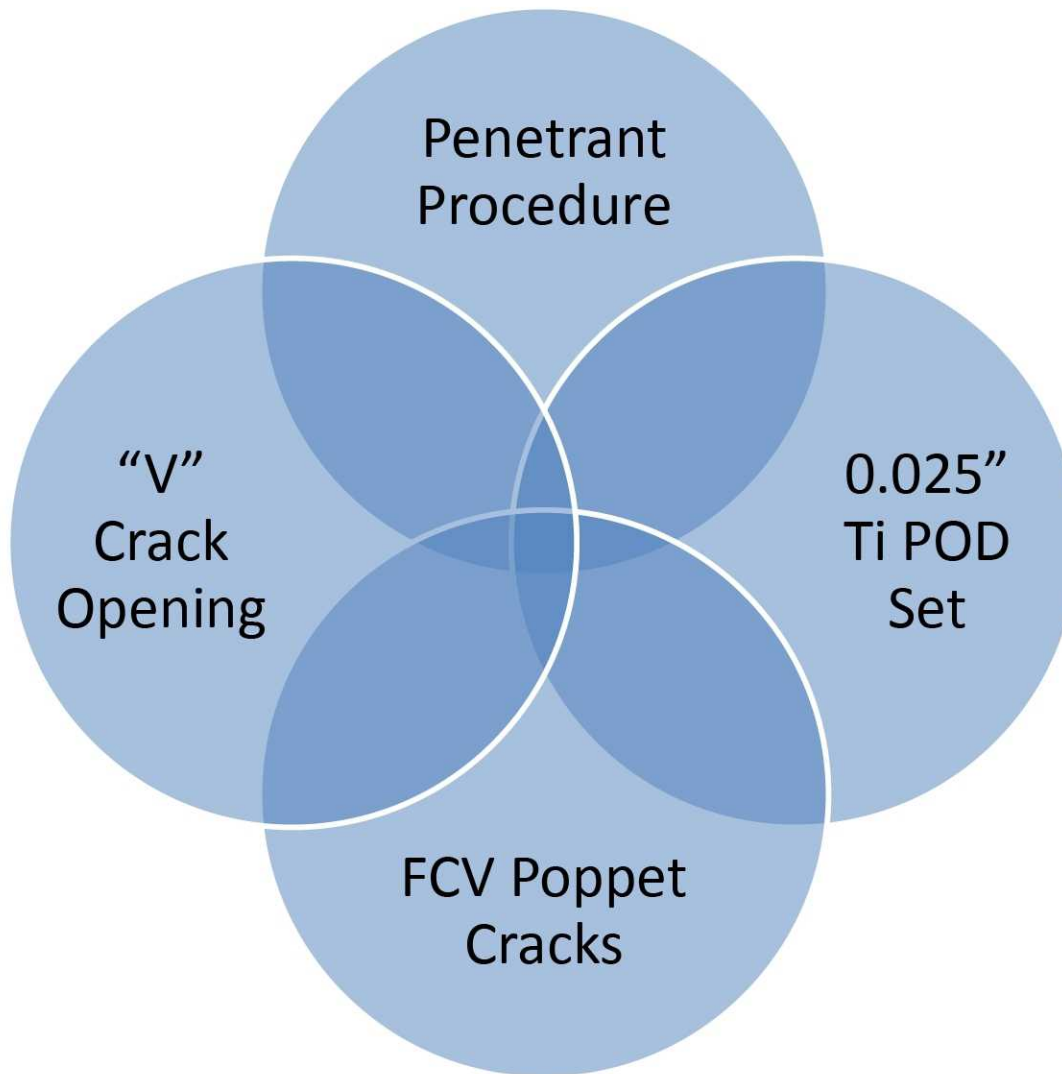
JSC Titanium POD Specimens Cont'

- Assessment of Contractor's 2008 qualification testing generated several questions about the quality of JSC's POD specimens
- JSC's POD specimens have "V" shape from etching
- Do not know how the width of the crack opening affects the crack detectability
- Cracks were contaminated with debris after returned to JSC from the Contractor





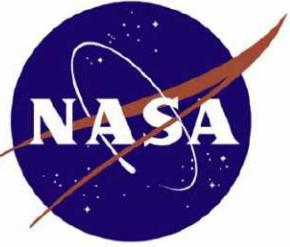
Project Outline



How comparable are POD cracks and in-service cracks?

How clean and detectable are the POD cracks?

Are the poppet cracks too tight for penetrant?



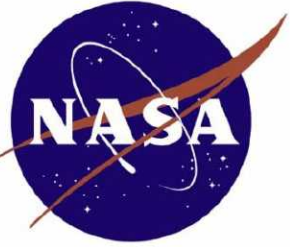
Project Procedure

"V" Investigation



- Cut out 1" square with the crack centered using diamond cut-off saw
- Document initial condition with SEM
- Perform Fluorescent penetrant
 - Spot of penetrant covering crack, P-136E
 - 15 – 30 minute dwell time
 - Dry wipe and solvent wipe
 - Photograph pre-developed state
 - Apply developer from aerosol spray can
 - Photograph post-developed state
 - Dry wipe off developer and repeat development process if necessary
 - Clean specimen



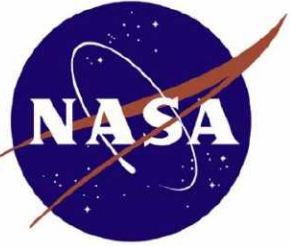


Project Procedure

"V" Investigation Cont'



- Sand off surface in 1 mil increments with grinding wheel
 - 500 grit ($18\text{ }\mu\text{m}$) followed by 800 grit ($12\text{ }\mu\text{m}$)
- Lightly etch Surface – Kroll (2% HF, 4% HNO_3 , 96% H_2O)
- Document again with SEM and perform fluorescent penetrant testing at each stage



Project Procedure

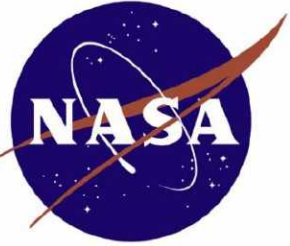
0.025" Titanium POD Specimens



- The set consisted of 51 cracks in a total of 19 specimens
- 29 of the cracks were in the test range of 0.023" – 0.027"
- The specimens were cleaned in an ultrasonic cleaner with de-ionized water at 65°C and verified with the SEM
- A similar penetrant procedure was used to give a rating of the indication under the UV light and photograph the indications

Rating	Description
1	Easily Detectable
2	Detectable
3	Barely Detectable
4	Undetectable

- The specimens were cleaned again in the ultrasonic cleaner



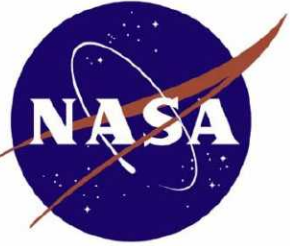
Project Procedure

Poppet Investigation



- Document Langley fatigue cracked and flight FCV poppets in SEM
- Perform penetrant (P-136E & P6F4) tests on Langley fatigue cracked poppets
 - Focused on largest cracks
 - Spot application
 - Solvent wipe



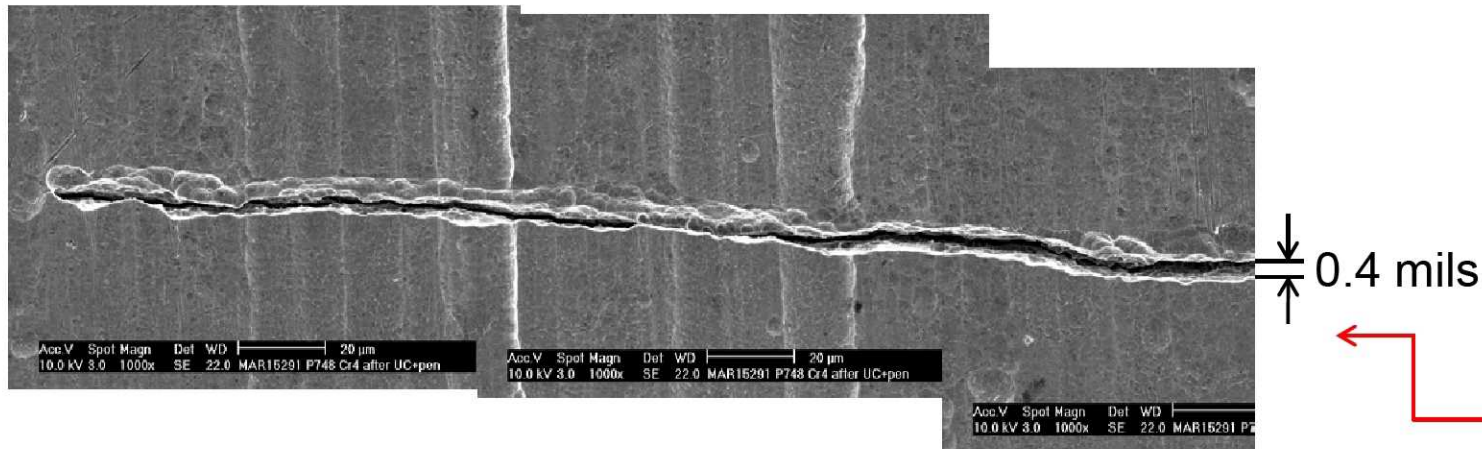


Results

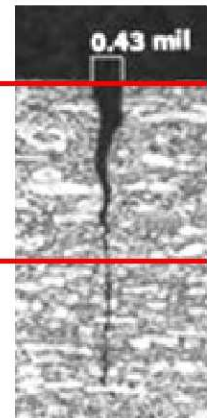
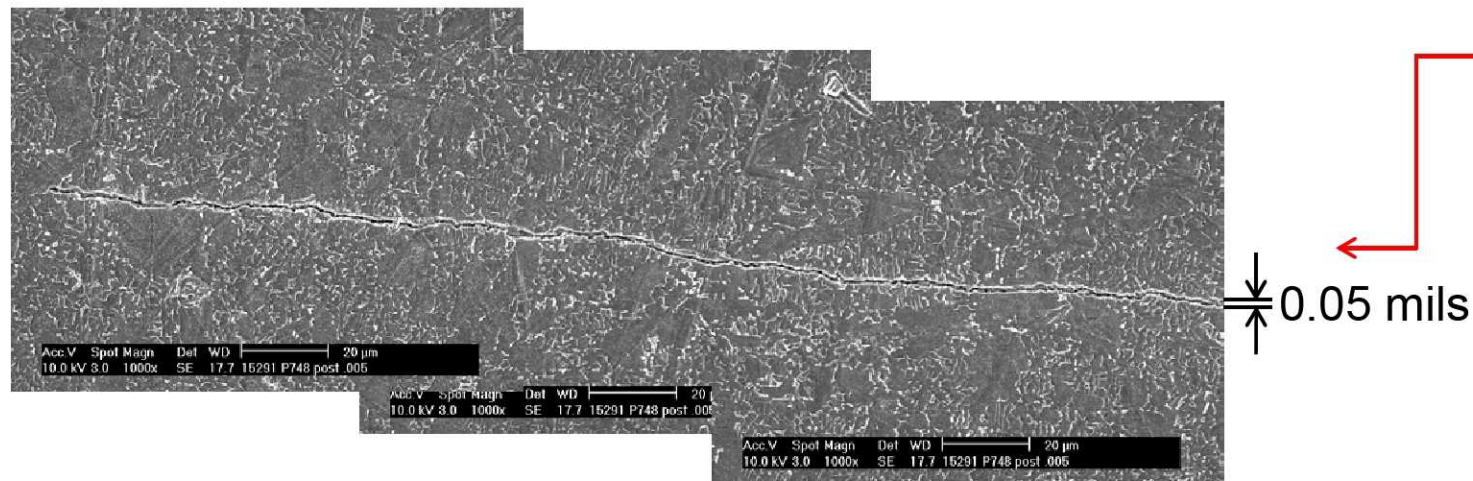


"V" Investigation SEM Photos

As Received

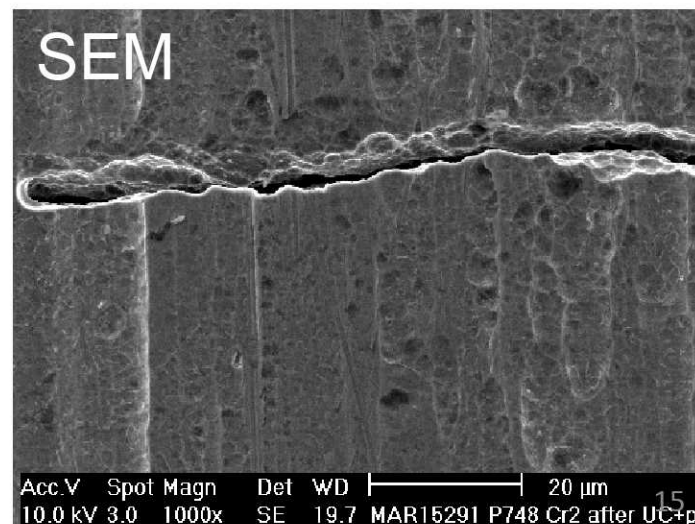


Post 5 mil Removal by Grinding





Inverted Light Microscope



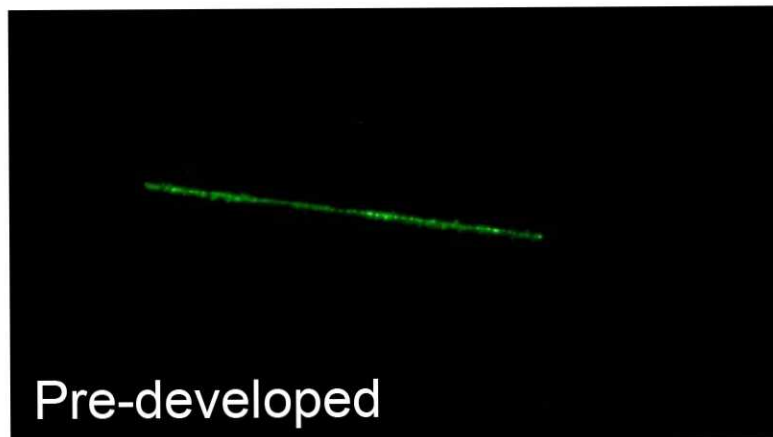


Results

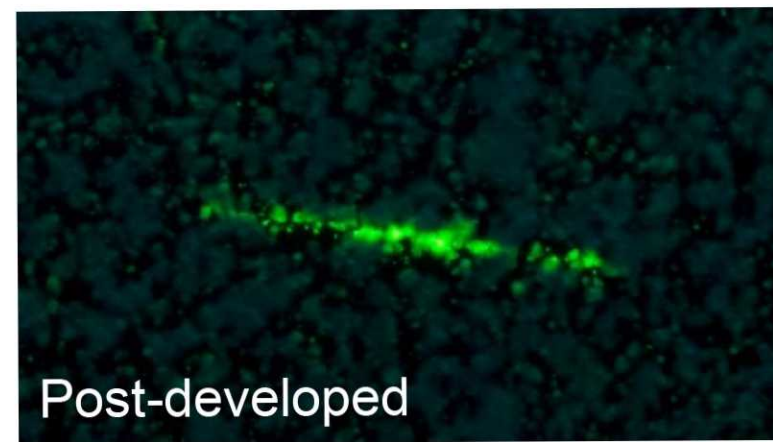
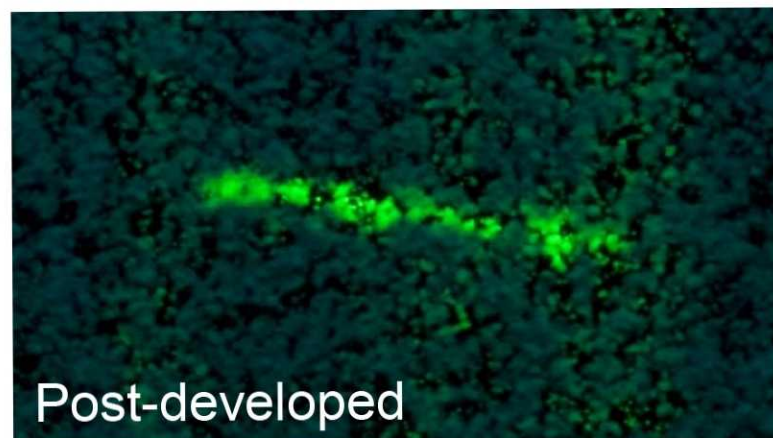
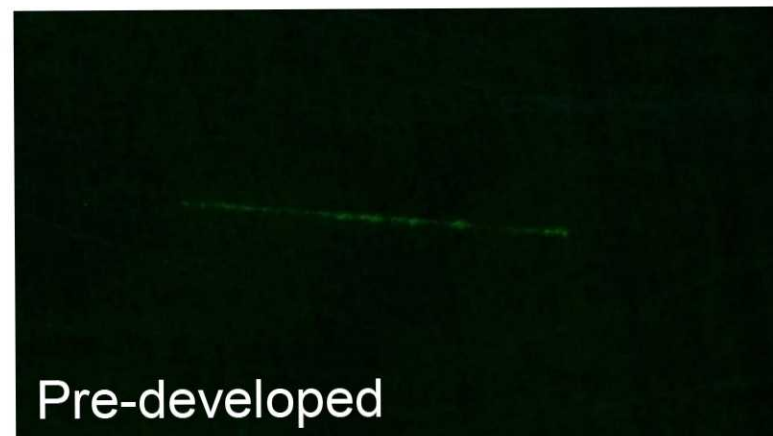
"V" Investigation Penetrant Photos



As Received



Post 5 mil Removal

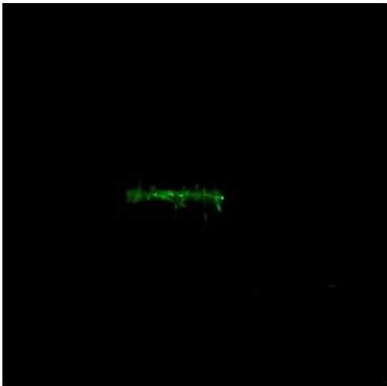
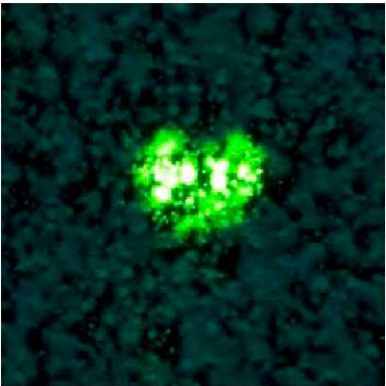

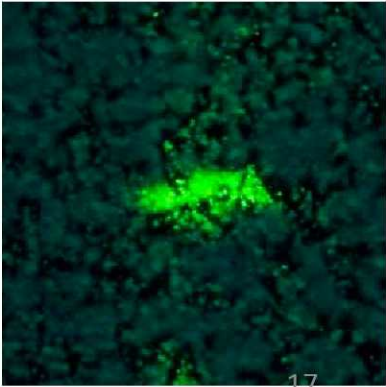




Results

0.025" Titanium POD Specimens



Specimen	Length (inches)	Pre-develop Rating	Post-develop Rating	Pre-develop Photograph	Post-develop Photograph
2Y19-3	0.025	1	1		
K703-2	0.026	1	1		

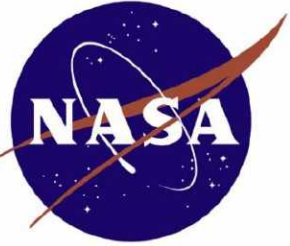


Results

0.025" Titanium POD Specimens



Specimen	Length (inches)	Pre-develop Rating	Post-develop Rating	Pre-develop Photograph	Post-develop Photograph
52P8-2	0.068	3	1		
36T4-1	0.013	3	2		



Results



0.025" Titanium POD Specimens

- From the testing we were able to determine all the cracks within the test range were detectable or better with developer
- Many of the indications after development lost their linearity and gave circular indications
- Our tests were performed in a laboratory and our procedure would be difficult in an industrial setting

Ratings	1	2	3	4
Pre-develop Cracks	23	14	8	1
Post-develop Cracks	40	8	2	1

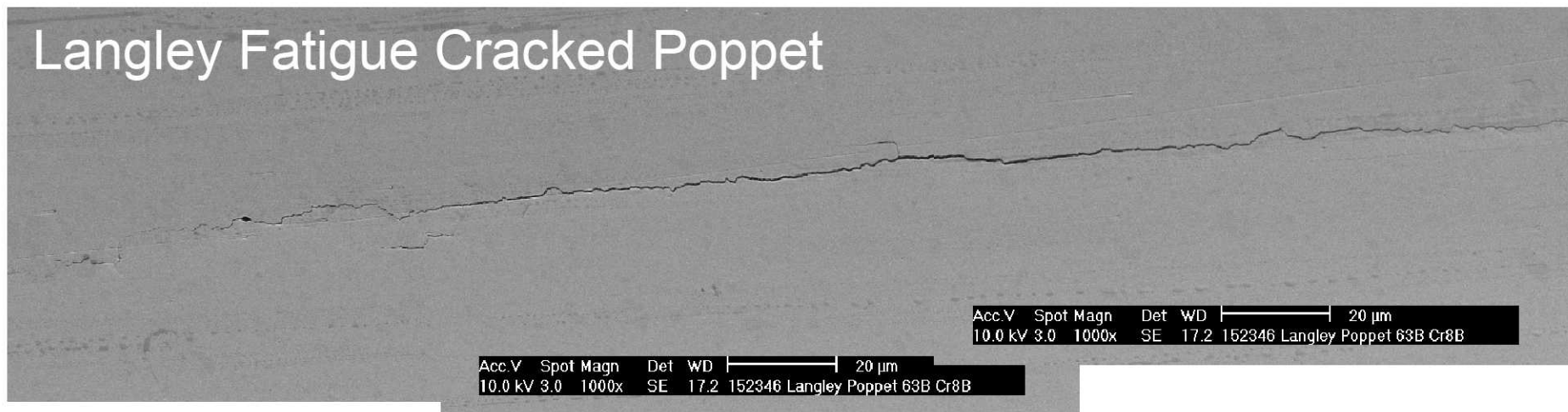


Results

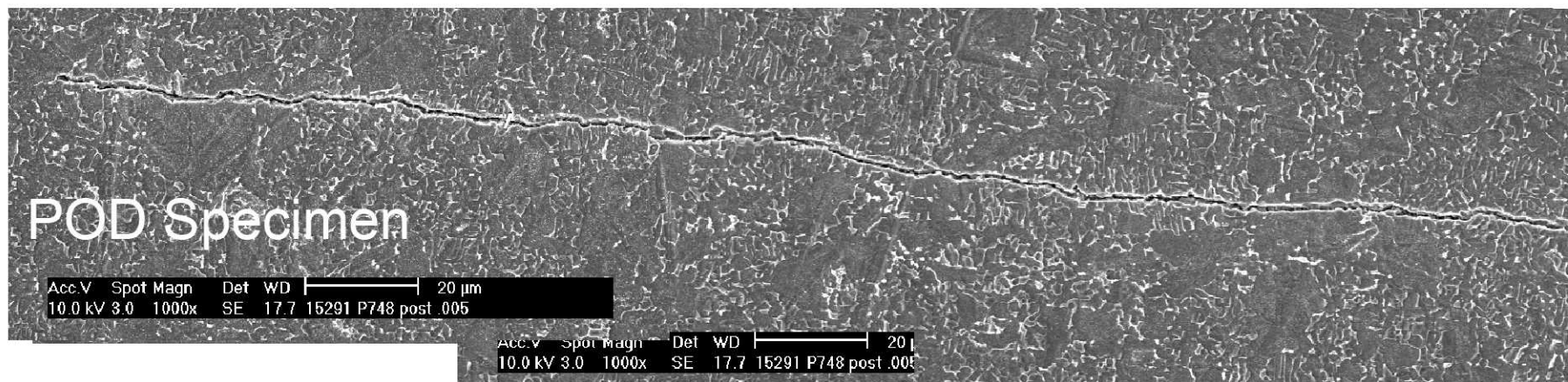
Poppet Investigation



Langley Fatigue Cracked Poppet



POD Specimen

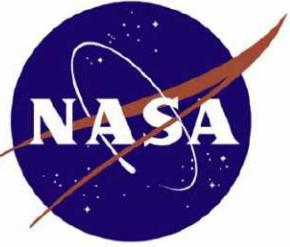




Conclusions & Future Work



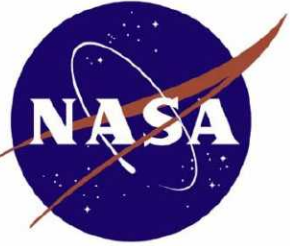
- The “V” did not significantly affect our ability to detect the POD cracks with fluorescent penetrant
 - Conduct same experiment with more cracks
- The 0.025 and 0.050 POD specimens are clean and documented with the SEM
 - Conduct water-wash fluorescent penetrant test at EAFB
- The poppet cracks are tighter than the POD specimen cracks
 - Flight FCV poppets: 0.01 mils (0.3 μm)
 - Langley fatigue cracked poppets: 0.02 mils (0.5 μm)
 - POD specimen (post 5 mils): 0.05 mils (1.4 μm)
- We could not detect cracks in Langley fatigue-cracked poppets with fluorescent penetrant
 - Investigate inability of penetrant to wet the poppet surface



What I Have Learned



- Lab procedures and safety
 - Data/procedure documentation
- POD methods and theory
- Fluorescent penetrant testing
 - Hands on and highly influenced by the inspector
- Eddy current testing and bolt inspection device for poppets
- Light Microscope with z-stack
- Metallurgy Camera with UV flash
- Fine grinding and polishing
- Metallurgical etching
- Heat Treatment



The JSC Experience



Lecture by Chris Kraft



Heat Treatment Videos

by: John Figert

STS-127 Crew Return

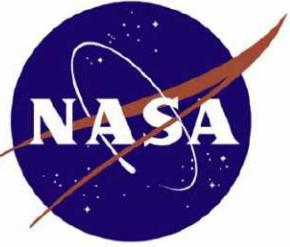




The Near Future



- After graduation I plan on acquiring a Masters Degree related to Aeronautical Engineering
- I would like to return to JSC or another center as a graduate Co-op
- After graduate school, I hope to start a career working for NASA



Acknowledgements and References



Acknowledgements

- Bud Casnter
- Ajay Koshti
- Louis Hulse
- James Martinez
- Glenn Morgan
- Eddie Pompa
- Norman Ruffino
- Veronica Seyl

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